

Science Monstrosity II: Science of the Lambs

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Tossups

1. Howard Florey and Ernst Chain discovered its structure, and resistance to it derives from the secretion of enzymes that cleave the amide bond in its beta-lactam ring. It functions by inhibiting the transpeptidase by forming a covalent bond with a serine residue at the active site of the enzyme, and since this complex does not undergo deacylation, the inhibition is irreversible. Joshua Lederberg showed that bacteria susceptible to it could be grown in its presence in a hypertonic medium, thereby obtaining protoplasts. Consisting of a thiazolidine ring fused to a beta lactam ring to which a variable group is attached, FTP, identify this antibiotic first discovered by Arthur Fleming.

Answer: penicillin

2. John von Neumann once suggested using it as a random number generator. It possesses a 2-cycle for values of its parameter greater than 3, and the graph of its Lyapunov exponent as a function of the parameter exhibit negative spikes at around 3.57 and onward, with each additional spike signifying another 2 to the nth cycle. It possesses a transcritical bifurcation when its parameter is 1, and when it is between 1 and 2, this equation will converge to a stable point. Other values of the parameter cause oscillations between values of 2, 4, 8, 16, 32, and so on, leading to its application in population dynamics. The original source of the Feigenbaum number, FTP, what is this quadratic map whose recurrence relation is $x_{n+1} = rx_n(1 - x_n)$?

Answer: logistic equation (or map)

3. In stellar interiors, it dictates that gravitational contraction should result in an increased luminosity. It can be derived from Boltzmann's transport equation and Liouville's theorem, and the mass given this name can be found in a gravitational system if the system's extent and all the mean square velocities are known. A series given this name is an expansion of the ideal gas law in powers of number density over volume and includes a compressibility factor to indicate deviation from ideal behavior. FTP, identify the shared name given to all these things, with a theorem of this name stating that if time averages are well defined and the system is bounded, the average potential energy will minus one-half times the average kinetic energy.

Answer: virial (theorem, expansion)

4. After synthesis, this compound crystallizes in colorless crystals and is insoluble in water, but dissolves in dilute solutions of caustic alkalis. On fusion with caustic alkali it yields benzoic acid, and before it was pulled from store shelves due to cancer concerns it was used as a laxative. It is obtained by heating phenol and phthalic anhydride with concentrated sulfuric acid and is dissolved in alcohol for use in experiments. Itself a weak acid, FTP, identify this chemical with formula $C_{20}H_{14}O_4$, a common indicator that is colorless in acid and turns pink in a basic solution.

Answer: phenolphthalein

5. It was discovered by William Herschel in 1787 and most information about it comes from pictures taken by Voyager 2. It is covered with impact craters and the valley Messina Chasmata, almost 1000 miles long, runs through one of the larger craters, Ursula. It contains more rock than Rhea, and many of its craters are still partially submerged, suggesting that the surface is relatively young. Its composition is similar to that of Ariel, but it is larger and its network of craters and faults is not as extensive. Sometimes referred to as a "dirty ice ball" satellite, FTP, identify this companion of Oberon and largest moon of Saturn.

Answer: **Titania**

6. Its receptor is a heterotetramer of two extracellular alpha subunits disulfide bonded to two trans-membrane beta subunits. In most nonhepatic tissues, it performs its function by increasing the number of certain plasma membrane transporters, while in the liver it works by helping to activate photodiesterase. Its production is partly regulated by hormones known as incretins, and it is infused directly into the liver through the hepatic portal vein. In addition to its better known function, it also stimulates lipogenesis and regulates transcription. Produced by the beta cells of the islets of Langerhans, FTP, identify this hormone whose task it is to regulate blood glucose levels.

Answer: **insulin**

7. In 1993, Peter Shor demonstrated that a quantum computer would render it obsolete. Daniel Bleichenbacher described the first practical adaptive chosen cyphertext attack against it using a redundancy function, and a method called blinding is used to thwart timing attacks. It is slower than DES and other symmetric cryptosystems, and it is important that the prime numbers used for it not be too close, which would allow attackers to find them by means of Fermat factorization. Since the 512-bit modulus was broken in 1999, it is recommended that moduli be at least 1024 bits long. Consisting of a system of private and public keys, FTP, what is this encryption system named for its inventors, Ron Rivest, Adi Shamir, and Leonard Adleman.

Answer: **RSA**

8. A mechanical analog of this device consists of two wheels on a shaft coupled to each other through a spring wound around the shaft, with external torque playing the part of voltage. One part of this device is a special type of comparator, sometimes constructed in digital ones with XOR gates. When not receiving input, the voltage-controlled oscillator that is part of this device will operate at the free-running frequency, and its capture range dictates the limits of this device's ability to acquire a frequency due to the low-pass filter that is usually at its input. Capable of modulation, demodulation, and signal generation, FTP, identify this electronic feedback circuit which produces an output frequency to match the frequency of its input.

Answer: **phase-locked loop**

9. The first approximation made in this model is to approximate the electron as a point-like charge and to model the atoms involved as spheres. Corrective measures in this model include taking into account the volume and electronegativity of the atoms and the non-equivalence between axial and equatorial positions can be seen in such molecules as phosphorous pentafluoride. To explain within the framework of this model why carbon is tetravalent, Linus Pauling proposed the idea of hybridization. Classifying molecules into such geometries as linear, tetrahedral, and bipyramidal, FTP, identify this molecular model in which repulsive forces between bonding pairs of electrons, free electrons, and non-bonding pairs is minimized.

Answer: **Valence Shell Electron Pair Repulsion** model (or **VSEPR**)(note: sometimes people pronounce the initials "vesper")

10. The first one was destroyed shortly after launch when the vehicle carrying it steered off course. The third one included a radiation detector to measure the Van Allen belts and similar Martian phenomena, while numbers 6 and 7 were launched with the purpose of searching for conditions suitable to extraterrestrial life

on Mars in flyby mode. Number 8 failed outright, so number 9 accomplished both its own objectives and those of 8, while the tenth and last one demonstrated Hadley-type circulation in the Venusian atmosphere. All of these were, FTP, spacecraft from what nautically named NASA program, designed to observe Mars and Venus in flyby?

Answer: Mariner

11. One example of this phenomenon is the reabsorption of the tadpole tail during metamorphosis in to a frog, as well as the sloughing off of the inner uterine lining. External signals that can trigger it include TNF-alpha and Fas ligand, while damage to the cell can cause Bcl-2 to trigger the release of Apaf-1, which in turn triggers this process. It is also the main process by which the HIV virus destroys T-cells and neurons use a factor protein normally present in mitochondria that induces it instead of caspases. Triggered by the binding of so-called "suicide" proteins, FTP, what is this process of programmed cell death?

Answer: apoptosis

12. In 1934, Thomas Cowling proved that no self-sustaining one could have an axis of symmetry, and Stanislaw Braginsky obtained valid solutions for it by assuming that the field it produced was almost axially symmetric. Thermal convection cannot drive it because it would require temperatures that were too high, but compositional convection can help. Since the iron at the Earth's core is hotter than the Curie temperature, it cannot hold a permanent field, but may help to stabilize this process, which it helps perpetuate through convective motions given rise to by Earth's rotation. FTP, identify this inductive effect which attempts to explain why the Earth has a permanent magnetic field.

Answer: dynamo effect (or theory or whatever)

13. The planet for which this quantity is greatest is Saturn, and it is the cause of low air pressure at the South Pole, which is more consistent with an altitude of about 3,300 to 4000 meters. Due to this, in the 17th century, pendulum clocks in French Guiana were slower than those in Paris, and 35 percent of the difference in acceleration from the Earth's poles to the line of zero latitude is due to this. It is also the cause of the precession of the equinoxes, which result from the gravitational forces of the sun and moon on it. Caused by the centrifugal force of a planet's rotation, FTP, identify this distortion of a planet's shape which turns it into an oblate spheroid rather than a sphere.

Answer: equatorial bulge

14. They are present in the earliest plant fossils and it is suspected that they evolved at a time when the Earth's soil was poor in nutrients. The nodulin genes activated during the early stages of nodule formation are the same genes that are activated during the development of their endo type, in which case a dense mantle forms over the surface of the root. In the more common ecto type, the mantle is absent and the hyphae extend inward by digesting small patches of the root cell walls. In either case, the plant benefits from increased water uptake, while the fungus receives a steady supply of sugars. An example of mutualism, FTP, identify this entity formed by the symbiosis of plant roots and fungi.

Answer: mycorrhizae

15. The search for a nonzero value of the electric dipole moment of the neutron is a direct test of the application of this theorem to hadrons. It is impossible to construct a quantum theory if this theorem is assumed to be violated, and a direct consequence is that each particle must have the same lifetime and mass as its antiparticle. One of the most sensitive tests of this theorem is the mass difference between a neutral kaon and its antiparticle, since only in kaons does there occur a violation of two of the three associated symmetries that this theorem addresses. FTP, identify this fundamental theorem of quantum mechanics which states that the product of time reversal, charge conjugation, and parity reversal is an exact symmetry of any interaction.

Answer: CPT theorem (accept PCT or TCP theorem, as well as time-charge-parity in any order before they are mentioned).

16. A field-effect transistor based on this effect functions by inducing it in the active region of the channel lying closest to the gate. Nitrogen undergoes it at around 1.8 mega-bar and 7000 Kelvin, and it occurs in single-valent systems as a move from strongly correlated to weakly correlated electrons. When the intra-atomic interactions dominate the inter-atomic ones, this process produces a magnetic semiconductor, and when the opposite is true, it produces a normally non-magnetic metal. Jupiter and Saturn may contain metallic hydrogen due to, FTP, what process in which an insulator under extreme conditions becomes a conductor, named for British physicist Neville?

Answer: Mott transition (or Mott-Hubbard or Mott-Anderson; if "Neville" is mentioned, their answer must actually contain the word "transition" or something equivalent, like "phase change")

17. The adiabatic form of this quantity is given by its isothermal form times the ratio of the heat capacity at constant pressure to heat capacity at constant volume, and for an ideal gas it is given by the pressure times the first Gruneisen constant. The thermal form is inversely proportional to the thermal expansion coefficient, and the square root of this quantity divided by the density yields the speed of sound in that material. Defined as minus the volume times the derivative of pressure with respect to volume, FTP, identify this quantity which gives the change in volume of a solid as the pressure on it changes.

Answer: bulk modulus

18. When reacted with water, these compounds form geminal diols and treating them with hydrazine reduces the carbon-oxygen bond to a CH₂ bond by way of the Wolf-Kishner reaction. Treating them with a Grignard reagent yields an alcohol with a substituted group from the reagent, while treatment with Tollen's reagent converts them to carboxylic acids without breaking the carbon-carbon double bond, and carboxylic acid can also be obtained by reacting them with oxidizing agents such as nitric acid. Synthesized by reacting a primary alcohol with an oxidizing agent such as pyridinium chloride, FTP, identify these organic molecules containing or consisting of a terminal carbonyl group.

Answer: aldehydes

19. It was established following a 1952 UNESCO conference and one of its earliest achievements was the observation of pion decay into an electron and a neutrino. In 1963 it built its first bubble chamber to observe neutrino interactions and it added a second laboratory, along with a 7-kilometer Super Proton Synchrotron in 1971. The W and Z bosons were discovered here, confirming electroweak theory, and in 1989 it opened its Large Electron-Positron collider which was inaugurated by Francois Mitterand. The site of Tim Berners-Lee's invention of the Internet, FTP, identify this research laboratory in Switzerland whose Large Hadron Collider is slated to become the most powerful accelerator in the world.

Answer: Conseil European pour la Recherche Nucleaire or CERN

20. The nervous system of animals in this phylum is biradially symmetric, with the central nervous system consisting of two parallel nerve cords connected by the transverse fibers of the peripheral system. Class Cestoidea lacks a digestive tract and has a scolex with hooks on the end, while monogeneans tend to infect the external surfaces of fish by means of a ciliated larva. In class Turbellaria's excretory system, nephron-like functions are performed by the flame cells, and all classes in this phylum have gastrovascular cavities with only one opening. Including planarians and the class Trematoda, FTP, identify this phylum of acoelomates better known as flatworms.

Answer: platyhelminthes

Bonuses

1. Answer some questions about logic FTPE. [10 points] In a Boolean logic system, this theorem states that "not quantity A plus B equals not A times not B" and "not quantity A times B equals not A plus not B."

Answer: **De Morgan's** Theorem

[10 points] In developing the mathematical foundation of intuitionism, Ludwig Brouwer explicitly rejected this law, which states that for every proposition p it must be true that p or not p.

Answer: **law of the excluded middle**

[10 points] This type of logic does not have completeness theorems and differs from a simpler type of logic in that it allows quantification over the subsets of a domain.

Answer: **second-order** logic

2. Answer some questions about quantum computation, FTPE.

[10 points] This is the quantum counterpart to the basic unit of information in classical computers.

Answer: **qubit**

[10 points] This is one of the basic operations in quantum computing, mapping the qubit basis states 0 and 1 to two superposition states with equal weight. It is named after a French mathematician whose transform is a generalization of the Fourier transform.

Answer: **Hadamard** transform (or rotation, or gate)

[10 points] One of the classical algorithms of quantum computing, this algorithm illustrates how to determine with a quantum computer whether a function is constant at 0 or 1, or whether it returns 0 for half the domain and 1 for the other half.

Answer: **Deutsch-Josza** algorithm

3. Answer some questions about elements FTPE.

[10 points] This phenomenon is caused by the increase in effective nuclear charge because the 4f electrons do poor job of shielding the nucleus.

Answer: **lanthanide contraction**

[10 points] Ligand effects in the calculation of paramagnetism of lanthanides are small in comparison with this type of coupling.

Answer: **spin-orbit** coupling (or **Russel-Saunders** coupling or **L-S** coupling)

[10 points] The 4f orbitals in lanthanides fill up before the 3d orbitals in accordance with this principle, which dictates that lower energy levels are filled before higher ones and is German for "building out."

Answer: **aufbau** principle

4. Answer some questions about physical systems FTPE.

[10 points] When the generalized coordinates are independent of time, this function is the sum of the kinetic and potential energies.

Answer: **Hamiltonian**

[5 points each] For systems undergoing periodic motions, a canonical transformation can be made to this set of variables consisting of the quantity obtained by integrating the Lagrangian with respect to time and a second quantity measured in radians.

Answer: **action and angle** variables

[10 points] This is the name of the transformation which yields the Hamiltonian from the Lagrangian. It can also be used to obtain the Maxwell relations in thermodynamics.

Answer: **Legendre** transform

5. Answer some questions about semiconductors FTPE.

[10 points] In semiconductors, this is the space between Brillouin zones in which no particles can be allowed. More commonly, it is thought of as the energy space between the valence and conduction bands.

Answer: **band gap**

[10 points] The Brillouin zones and the band gap can be derived using this model, in which ionic cores are represented as an infinitely repeating series of square wells that narrow to delta functions.

Answer: **Kronig-Penney** model

[10 points] In order to derive the band gap from the Kronig-Penney model, it is necessary to make use of this theorem, which states that for a periodic potential, the wave function is the product of an exponential and a function with the same period as the potential.

Answer: **Bloch** theorem

6. Answer some questions about the structure of proteins, FTSNOPE.

[5 points each] The secondary structure of proteins can be of two varieties. In one case, it is a coil held together by hydrogen bonds every fourth amino acid, while in the other case, two regions of the polypeptide chain lie parallel to each other.

Answer: **alpha helix and beta sheet** (or **pleated sheet**)

[10 points] At the level of tertiary structure, when non-polar amino acid chains are close together, their structure can be strengthened by these forces, which arise from induced dipole interactions.

Answer: **Van der Waals** forces

[10 points] In order for proteins to exhibit quaternary structure, they must consist of more than one peptide chain. What is the term for such proteins?

Answer: **oligomeric**

7. Answer some questions about viruses, FTSNOPE.

[5 points] This is the term for the protective protein shell that encloses the viral genome.

Answer: **capsid**

[10 points] Exemplified by the T4 phage's weakening of an E. coli cell wall, leading to rupture, this is the phage reproduction pathway that leads to the death of the host cell.

Answer: **lytic** cycle

[5 points] Viruses such as HIV are given this term because they are equipped with reverse transcriptases.

Answer: **retroviruses**

[10 points] In contrast to the lytic cycle, this reproductive pathway used by the lambda phage replicates the viral genome without destroying the host.

Answer: **lysogenic** cycle

8. Answer some questions about the laws that govern reaction rates FTPE.

[10 points] This eponymous equation dictates that, other things being equal, the reaction rate increases exponentially with temperature.

Answer: **Arrhenius** equation

[10 points] For a reaction in equilibrium, this law holds that the product of the concentrations of products over the product of the concentration of the reactants, each raised to the stoichiometric coefficient, is a constant.

Answer: **law of mass action** (or **ideal law of chemical equilibrium**)

[10 points] This would be the order of a reaction which does not depend on the concentration of the reactants.

Answer: **0**

9. Answer some questions about the atmosphere of the sun, FTSNOPE.

[5 points] Beginning at about 20,000 kilometers above the photosphere, this is the outer layer of the sun that extends outward to several solar radii and has a temperature of about 1.5 million Kelvin.

Answer: **corona**

[10 points] The corona is the source of this phenomenon, which is the result of the corona's being so hot that

the Sun's gravity cannot retain it. It travels at roughly 400 meters per second and carries with it magnetic clouds.

Answer: **solar wind**

[15 points] Since the solar wind forces particles outward away from the sun, leaving vacuum behind. This is the term for the gradually expanding bubble left behind in the wake of the solar wind.

Answer: **heliosphere**

10. Identify these things related to an important organic molecule FTSNOPE.

[5 points] What is the tetrameric, iron-based protein whose function it is to bind molecular oxygen, and whose allosteric properties differentiate it from a similarly named molecule?

Answer: **hemoglobin**

[10 points] There are six coordination sites around the central iron atom in the heme, four of which are occupied by nitrogen, forming this type of planar ring.

Answer: **porphyrin** ring

[15 points] An increase in CO₂ concentration results in the dissociation of oxygen from hemoglobin due to this effect, in which hydrogen ions cause the release of oxygen and which bears the name of a famous physicist.

Answer: **Bohr** effect

11. Answer some questions about igneous rocks, FTSNOPE.

[10 points] Igneous rocks can be classified according to the concentration of this mineral with a Mohs hardness of 7 and chemical formula SiO₂.

Answer: **quartz**

[5 points each] Igneous rocks can also be classified according to their concentrations of light or heavy elements. Give the two names used to designate these classes.

Answer: **felsic and mafic**

[10 points] Chemically equivalent to basalt, this plutonic rock is formed when molten magma is trapped under the surface and cools.

Answer: **gabbro**

12. Answer some questions about dimensionless numbers FTSNOPE.

[10 points] The dimensionless units in fluid mechanics can be derived from the application of this theorem, which states that physical laws must be homogenous in all dimensions.

Answer: **Buckingham** Pi theorem

[15 points] This dimensionless number, the ratio of mean free path to a representative length scale, allows differentiation between diffuse and molecular flow regimes.

Answer: **Knudsen** number

[5 points] The best-known of the dimensionless numbers, it differentiates between turbulent and laminar flow.

Answer: **Reynolds** number

13. Answer some questions about problems involving chess pieces FTPE.

[10 points] In this problem one attempts to move a certain chess piece in such a way that the piece moves through every square just once and returning to the starting square.

Answer: **Knight's Tour**

[10 points] Another problem involves placing eight of these pieces on a standard board in such a way that none of them attacks the other.

Answer: **queen**

[10 points] Both knight's tours and the queen problem can make use of the theory of these objects, whose

every row, column, and diagonal sum to the same number.

Answer: **magic squares**

14. Answer some questions about compilers FTPE.

[10 points] This is a type of grammar in which every production rule relates a non-terminal symbol V to a string consisting of terminals and nonterminals, w . It takes its name from the fact that w can always be substituted for V regardless of location.

Answer: **context-free** grammar

[10 points] This is the program that performs the analysis of the grammatical structure of a computer language during compilation with respect to a given grammar.

Answer: **parser**

[10 points] Often called as a subroutine from the parser, this type of analyzer converts the source program into a sequence of tokens.

Answer: **lexical analyzer**

15. Identify these things having to do with sampling, FTPE.

[10 points] This effect causes continuous signals to become indistinguishable when sampled at incorrect frequencies. Moivre patterns are one example of it.

Answer: **aliasing**

[10 points] This theorem says that to avoid aliasing, the sampling frequency must be twice the frequency of the finest component you wish to resolve.

Answer: **Nyquist-Shannon** sampling theorem

[10 points] This type of filtering transformation satisfies the superposition condition.

Answer: **linear** filter

16. Answer some questions about photosynthesis, FTPE.

[10 points] These sites of photosynthesis consist of a thylakoid membrane that encloses grana surrounded by the stroma.

Answer: **chloroplast**

[10 points] This type of electron flow in chloroplasts uses electrons excited in photosystem II to produce ATP during the transfer of electrons to photosystem I, after which excitation in photosystem I leads to NADPH production.

Answer: **non-cyclic** electron flow

[10 points] ATP is created during both cyclic and non-cyclic electron flows through this reaction, which takes its name from the fact that it is driven by light.

Answer: **photophosphorylation**

17. Identify these things related to plasmas FTPE.

[10 points] Used to determine the temperature, density, and distribution function of a plasma, this measuring device is a small conducting probe which is biased and then inserted into the plasma.

Answer: **Langmuir** probe

[10 points] Under the appropriate conditions, a plasma may have a negative number for this value, causing beams propagating through the plasma to bend away, rather than towards the normal at boundaries.

Answer: **index of refraction**

[10 points] Observed in most reactors, this type of diffusion was proposed by its namesake on the basis of empirical results, and scales as one over the magnetic field, rather than as one over the magnetic field squared.

Answer: **Bohm** diffusion

18. Identify these things related to evolution FTPE.

[10 points] Beginning about 545 million years ago, this is the term given to the burst in animal origins the evidence for which is best preserved in the fossil record of the Burgess Shale.

Answer: **Cambrian** explosion

[10 points] Plants are believed to have evolved from these green algae which have homologous chloroplasts, similar division mechanisms, and a close genetic relationship with plants.

Answer: **charophytes**

[10 points] An important point in the evolution of animal life was the duplication of this gene complex, which occurred 520 and 425 million years ago. These gene complexes are responsible for regulating the spatial arrangement of body parts.

Answer: **homeotic** gene complex or **Hox** or **homeobox**

19. Answer some questions about the chemistry of the atmosphere, FTPE.

[10 points] This is the collective name for the aliphatic compounds which contain elements 6, 9, 17, and possibly other halogens and hydrogen, including all types of freons.

Answer: **chlorofluorocarbons** (or **CFCs**)

[10 points] The photodissociation of CFCs leads to the formation of these types of molecules which have incomplete electronic octets and contribute to the catalytic destruction of ozone.

Answer: **free radicals**

[10 points] An attempt to produce a fuel that was more readily oxidized and would decrease the resulting tropospheric ozone production led to the blending with gasoline of this chemical, which was banned in California after it was found that it is toxic to fish and can render groundwater unusable.

Answer: **methyl tertiary butyl ether** (or **MTBE**)

20. Since this tournament is coming to you from sunny California, it's only appropriate that there be a weather bonus in it. FTPE:

[10 points] Used in most models of global atmospheric flow, this is the term for the set of equations that combines the equations of motion, the hydrostatic equation, the continuity equation, and the first law of thermodynamics, suggesting their basic nature.

Answer: **primitive** equations

[10 points] These regions, typically extending from about 30 to 35 degrees latitude both north and south of the equator are boundaries between the Hadley and the Ferrel cells.

Answer: **horse latitudes**

[10 points] This is the warm Atlantic current that flows along the eastern United States and makes Ireland, Britain, and Scandinavia warmer than they would ordinarily be.

Answer: **Gulf Stream**